B4 Con'd

(a) means for generating a first interference within said optical beam having a first free spectral range corresponding to a spacing between adjacent gridlines of said selected wavelength grid; and

(b) means for generating a second interference within said optical beam having a second, tunable free spectral range.

## REMARKS

After entry of this Amendment claims 59-87 are pending in this application. New claims 59-87 are fully supported throughout Applicant's specification and in the drawings, and introduce no new matter.

### 2. Objection to the drawings under 37 CFR 1.83(a)

The drawings were objected to under 37 CFR 1.83(a) as failing to show the "logic" element present in the originally presented claims.

New claims 59-87 do not recite a logic element.

### 3. Objection to the drawings under 37 CFR 1.84(p5)

The drawings were objected to under 37 CFR 1.84(p)(5) as failing to include the reference signs FIGS. 4A-B on page 9 lines 23, 29 and on page 11, line 2.

The specification has been amended to correct errors in the Specification in which FIG. 4 was referred to as FIGS. 4A-B. The Applicant apologizes for any inconvenience resulting from this error.

### 4-5. Objection to informalities in the disclosure

The Examiner objected to the language "FIGS. 2AB" in the specification, and Applicant was

directed to insert a hyphen between A-B. Applicant has amended the specification accordingly.

Objections were raised to a perceived lack of agreement between "Equation 1B on Page 16, line 4 and a following sentence: "Thus the $FSR_{ChanSel}$ differs from the $FSR_{GridGen}$ by an amount substantially corresponding to 1/M * $FSR_{GridGen}$." found on page 16 lines 6-8.

The Applicant respectfully believes that there is no lack of agreement between Equation 1B and the above referenced sentence. Equation 1B expresses the free spectral range (FSR) of the channel selector in terms of a fraction "M/(M±1)" of the FSR of the grid generator. The referenced sentence expresses the magnitude of the difference between the respective FSRs. By way of example if M the total number of channels e.g. 100, then the fraction "M/(M±1)" equals either 100/99 = 1.0101 or 100/101 = .990099, and the FSR of the channel selector differs from the FSR of the grid generator by amounts 0.0101 or .009901, both of which approximate or substantially correspond to 1/M = 0.0100. Thus, the sentence at page 16 lines 6-8 identified by the Examiner accurately reflects the relationship of Equation 1B.

## 6-7. Rejection of Claims 34, 37-40 and 53-58 under 35 U.S.C. 112 second paragraph

Claims 34, 37-40 and 53-58 were rejected under 35 U.S.C. 112, second paragraph as being indefinite. Particularly, the Examiner stated that the term "substantially" in the claims was said to be overbroad and not to constitute a limitation in any patentable sense. The rejected claims have been canceled. New claims 59-87 do not recite the term "substantially".

## 8. Rejection of Claims 53-58 under 35 U.S.C 112 sixth paragraph

Claims 53-58 were rejected under 35 U.S.C., sixth paragraph. The Applicant has canceled claims 53-58.

## 9-10 Rejection of Claims 33-58 under 35 U.S.C. 103(a)

Claims 33-58 were rejected under 35 U.S.C. 103(a) as being unpatentable over Zorabedian (6,108,355) in view of Wu (5,606,439). The Examiner stated that Zorabedian '355 teaches a

communication apparatus "comprising a grid generator suitable for positioning in an optical path of a beam and a channel selector with a tunable second optical path length to select one the number of channels of the wavelength grid". The Examiner cited col. 1 lines 28-42 and FIG. 5B of Zorabedian. The Examiner further stated that Zorabedian did not teach the discreteness of each channel, but that Wu '439 teaches tuning to discrete channels.

The Applicant respectfully disagrees with the Examiner. There is no teaching or suggestion of a grid generator, or the generation of transmission peaks or pass bands corresponding to channels of a wavelength grid, or the use of vernier tuning, in the Zorabedian '355 reference, either at the portion of the specification identified by the Examiner or elsewhere in the specification. The Zorabedian reference discloses a *continuously* tunable laser with a filter element (162) that is continuously tunable over a wide wavelength range. The tunable filter 162 of Zorabedian '355 is a "wedge-shaped air gap" that generates a single passband which is continuously tunable across a wide tuning range (see, e.g., col. 4 Lines 8-16). Wu '439 discloses a tunable filter 26 that, like the filter of Zorabedian '355, generates only a single pass band that is continuously tunable across a wide wavelength range (See, e.g., col. 3, Lines 57-59 of Wu). There is no teaching or suggestion in the Wu reference of using a grid generator to generate transmission peaks or pass bands corresponding to channels of a wavelength grid. Both the '355 and '439 tuning elements generate only a single tunable passband within the wavelength range of interest.

In Applicant's invention, a grid generator 246 defines one set of multiple pass bands or transmission peaks corresponding to a communication grid, and a separate channel selector 252 defines a second, different set of multiple pass bands or transmission peaks that are tuned with respect to the first set of transmission peaks. The grid generator 246 and channel selector 252 together act as vernier tuned filter such that a single loss minimun is tunable across the wavelength grid, with the channel selector 252 supporting lasing at the center wavelength of a selected channel while attenuating the other channels of the wavelength grid. (see p. 8 lines 9-14, p. 9 lines 18-25, p. 10 line 9 through p. 11 line 2, and FIG. 4 and FIG. 5AA-C of Applicant's disclosure).

Each of Applicant's new apparatus claims expressly recites a grid generator positioned in an optical path and configured to generate a first set of transmission peaks corresponding to channels of a selected wavelength grid; and a channel selector positioned in the optical path and configured to

generate a second set of transmission peaks. Applicant's new method claims similarly recite generating a first set of transmission peaks corresponding to channels of a selected wavelength grid, generating a second set of transmission peaks, and tuning the second set of transmission peaks with respect to the first set of transmission peaks to tune an optical beam.

As noted above, neither Zorabedian '355 or Wu '439, considered either singly or together, disclose or suggest the use of a grid generator to define a first set of multiple pass bands corresponding to a wavelength grid, or a channel selector that defines a second set of pass bands, and the use of such a grid generator and channel selector together for tuning an optical beam. Accordingly, the Applicant respectfully submits that new claims 59-87 are patentably distinct from the teachings of Zorabedian '355 and Wu '439.

Conclusion

In view of the foregoing, the Applicant believes that each of the presently pending claims recites patentable subject matter and is in condition for allowance. Accordingly, it is respectfully requested that the outstanding claim rejections be withdrawn, and that this case be passed to issuance.

Attached hereto is a marked-up version of the changes made to the specification and claims by the current amendment. The attached page is captioned "Version with Marking to Show Changes Made."

The Commissioner is hereby authorized to pay any underpayments of fees associated with this communication, including any necessary fees for extensions of time, or credit any overpayment to deposit account No. 50-0815, order No. NUFO 021.

Respectfully Submitted,
BOZICEVIC, FIELD & FRANCIS LLP

Robert C. Hall
Reg. No. 39,209

BOZICEVIC, FIELD & FRANCIS LLP
200 Middlefield, Suite 200
Menlo Park CA 94025
(650) 327-3400
(650) 327-3231

VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE SPECIFICATION

Please see the attached marked-up version of the specification.

IN THE CLAIMS

Please cancel Claims 33-58 without prejudice.

of the line card in the embodiment shown is duplex, meaning that bi-directional communications are possible. Thus, the same device operates as a multiplexer and de-multiplexer.

FIGS. ~~2AB~~ 2A-B are isometric side and top views respectively of a tunable external cavity laser with a vernier tuned filter according to an embodiment of the current invention. The laser cavity is delimited by the partially reflecting rear facet 226 of the gain medium/laser amplifier 224 and by an external retroreflector 264. Tunable feedback to control the lasing wavelength is provided by the external cavity which is optically coupled to the anti-reflection (AR) side 228 of the gain medium. The effective reflectivity of the external cavity should be much greater than the residual reflectivity of the AR coated front facet so that the vernier tuned filter 290 can deliver sufficient feedback to put the laser in the "strong feedback" regime. The vernier tuned filter includes in this embodiment, grid generator 246 and the channel selector, e.g., interference filter/etalon 252. The external cavity laser also includes lens 242, channel tuner 254, grid control 248, base 260, output coupling optics 212, and fiber optic 206. The laser amplifier 224 in the embodiment shown is a laser diode.

Structurally, the tunable laser is shown laid out along an optical path 208. Coupling optics 212 are positioned between the back facet 226 of the laser 224 and a fiber optic 206. The laser and coupling optics are mounted to the base 260 by individual mounts 222 and 210 respectively. The fiber optic is coupled by ferrule 204 to an optical coupler 202 which is in turn coupled to base 260. The laser amplifier, in an embodiment of the invention, is a conventional Fabry-Perot laser diode. The front and rear facets 228-226 of the laser diode are aligned with the longitudinal axis 208. The front facet has an AR coating with a reflectivity of less than 0.5 %. The rear facet in this embodiment includes a partially reflecting dielectric coating. The proximal end of the external cavity is located at the front facet 228 of the laser diode. The distal end of the external cavity is defined by the retroreflector 222. The cavity itself extends from the rear facet of the gain medium to the retroreflector. The retro reflector 264 is coupled to base 260 via mount 262.

Within the cavity, a channel selector 252, grid generator 246, and cavity-coupling lens 242 are mounted coaxially with the optical path 208. The cavity-coupling lens is attached via mount 240 to the base 260 proximate to the front facet



U.S. Application Serial No. 09/626,526
Attorney Docket No. NUFO-021
Robert C. Hall (650) 327-3400
Bozicevic Field & Francis LLP

228 of the gain medium 224. This lens(es) reshapes the divergent beam emitted from the gain medium for proper coupling to the external cavity. The grid generator in the embodiment shown is a temperature stabilized etalon that precisely references a selected wavelength grid by allowing feedback to the laser of pass bands centered about the wavelengths of the selected wavelength grid, on which communication channels will be established. In the embodiment shown the optical characteristics of the grid generator are temperature controlled so as to maintain alignment between the pass bands of the grid generator and a selected wavelength grid. The temperature of the grid generator may be controlled via a first thermal actuator 244 under the control of the grid controller 248. In the embodiment shown the first thermal actuator couples the grid generator to the base 260. In an alternate embodiment of the invention the first thermal actuator extends the full length of the base 260, and is used to temperature regulate all components within the cavity with the exception of the channel selector which is separately temperature regulated. The grid controller 248 contains logic for controlling, via temperature, the pass band characteristics of the grid generator. This may include closed loop feedback of temperature, wavelength etc.

The grid generator 246 operates as a filter, e.g., an interference filter with a thickness Lg and index of refraction $n_g$ chosen such that its loss spectrum comprises a multiplicity of minima within the communications band at wavelengths that coincide with the center wavelengths of the selected wavelength grid. More generally the grid generator filter function results in a plurality of passbands centered on each of the gridlines of the selected wavelength grid. (See FIGS. 4A-B and 5A-C). The grid generator has a finesse that suppresses neighboring modes of the laser between each channel. In this embodiment of the invention the grid generator is an interference element, e.g., a parallel plate solid/gas etalon. The grid generator is precisely dimensioned to have a free spectral range ($FSR_{Grid\_Gen}$) corresponding to the spacing between wavelengths/gridlines of a selected wavelength grid, e.g., an ITU grid (See FIGS. 4A-B and 5A-C). In this embodiment of the invention the grid generator is fixed to the base 260.

In alternate embodiments of the invention the grid generator or channel selector may be implemented with a diffraction element, an interference element, or a



U.S. Application Serial No.
09/626,526
Attorney Docket No. NUFO-021
Robert C. Hall (650) 327-3400
Bozicevic Field & Francis LLP

birefringent element. In still another embodiment of the invention, the gain medium itself may serve as part of the vernier tuned filter 290, as either the grid generator or the channel selector. In this embodiment both facets of the gain medium would retain some reflectivity and comprise the grid generating or channel selecting element. In general the free spectral range of the etalon thus formed would depend on temperature, diode current and photon flux. Properly controlled, the combination of optical feedback from the diode facets and that provided by the external cavity would yield the same vernier tuning behavior.

The channel selector 252 also operates as a filter, e.g., a Fabry-Perot filter, an interference filter, etc., with constructive interference, that results in a plurality of passbands differing from the first pass bands by an amount corresponding substantially inversely with the number of channels of the selected wavelength grid. This relationship allows "vernier" tuning of the output wavelength of the laser to a selected wavelength on the wavelength grid. The finesse of the grid generator and channel selector is chosen to suppress channels adjacent to the selected channel. In an alternate embodiment of the invention the second pass bands have a periodicity corresponding with the gain bandwidth of the gain medium.

In this embodiment the channel selector includes a gas or solid etalon 252. The etalon includes opposing planar first and second reflectors which are highly reflective, e.g., R>90%. The channel selector is dimensioned to have a free spectral range ($FSR_{Channel\_Selector}$) differing from that the grid generator ($FSR_{Grid\_Gen}$) by an amount corresponding substantially inversely with the number of channels in the wavelength grid. Both free spectral ranges of the grid generator and channel selector are broader than the free spectral range of the cavity ($FSR_{Cavity}$) (See FIG. 4~~A-B~~ and FIGS. 5A-C). In an embodiment of the invention, the FSR of the channel selector differs from the FSR of the grid generator by an amount which substantially corresponds to the quotient of the channel spacing and the number of channels in the wavelength grid, e.g., an ITU grid (See FIG. 4~~A-B~~ and FIGS. 5A-C). Vernier tuning of the channel selector results in a single loss-minimum within the communications band which can be tuned across the grid. The combined feedback to the gain medium from the grid generator together with the channel selector supports lasing at the center



U.S. Application Serial No.
09/626,526
Attorney Docket No. NUFO-021
Robert C. Hall (650) 327-3400
Bozicevic Field & Francis LLP

wavelength of the selected channel and substantially attenuates all other channels (See FIG. 4A-B and FIGS. 5A-C).

Channel selection in this embodiment of the invention is brought about by changes in the optical path length 256 of the channel selector. This in turn may result from either or both a change in the index of refraction of the channel selector 252 or of its thickness along the optical path, which in this case is aligned with the "z" axis. In the embodiment shown, the second thermal actuator 250 provides a temperature sink/source to decrease/increase the temperature of the channel selector 252 under the control of the channel tuner 254. This decreases/increases the optical path length of the channel selector. The FSR of the channel selector varies during tuning, but the variation is slight, e.g., less than +/- 1%. This is a result of the fact that the tuning range of the channel selector is limited to a range of one channel spacing within the wavelength grid.

The temperature control of the device may include individual temperature control of: the grid generator 246, the base 260, and the gain medium 224. The channel tuner and the grid control include logic for tuning the channel selector 252 and for maintaining the reference characteristics of the grid generator 246 respectively. These modules may be implemented separately or in combination. They may be implemented with open or closed loop feedback of temperature, wavelength, position etc. A single processor with appropriate program code and lookup table(s) may be used to control both the channel tuner and grid control. In an embodiment of the invention the lookup table contains data or formula which correlate wavelength of either/both the channel selector 252 or the grid generator 246 with the control variable(s). In the above discussed embodiment the control variable is temperature. In alternate embodiments of the invention the control variable(s) include: position, rotation, temperature, electrical parameters, electro-optic parameters etc. The lookup table(s) may contain a formula or a plurality of records which correlate the pass band characteristics of either or both the channel selector and the grid generator with a specific control variable, e.g. tuning parameter, appropriate for the manner in which selector /generator is being tuned/regulated. Tuning/regulation may be accomplished by mechanical, electrical or opto-electrical tuning device. Mechanical parameters include positions of the channel selector, (See FIG. 3A).



U.S. Application Serial No.
09/626,526
Attorney Docket No. NUFO-021
Robert C. Hall (650) 327-3400
Bozicevic Field & Francis LLP